ter at least four or five times that of the sun. Both these features lasted only a few minutes, when the sky resumed an aspect of clearness.

All of these features could be produced by, and only by, thin hexagonal plates of ice with their crystalline axes steadily vertical, or, in other words, with the plates persistently horizontal. The paranthelion, the explanation of which has given so much trouble to theorists, is produced by successive total interior reflections from vertical faces inclined at 120°, according to a general theory of halos which I have developed in a paper published in the MONTHLY WEATHER REVIEW, June, 1920, **48:** 322–330. As these crystals were the only effective ones in this particular display, the evidence in favor of the theory seems very conclusive.

Certain peculiarities of all the phenomena described I do not remember having seen noted before. These are, first, their very short duration, which in every case was determined by clearing of the sky, which must have been by evaporation of the crystals, not by transportation of the ice fog; second, the considerable size of the paranthelion. These argue a very small size for the individual crystals. Perhaps only such can possess great stability of direction in the atmosphere.

There is one feature of halos of which the theory is still in an unsatisfactory state, and that is the often-seen 46° circle. According to the long-accepted theory, this is produced by right-angled refracting edges with wholly random directions, just as the 22° circle is produced by 60° prisms. This theory has seemed to me questionable, a doubt founded chiefly upon my own very limited observations. Hence I have in the paper above cited offered an explanation which attributes the feature to horizontally directed crystals. If this circle is ever seen as quite uniform in brightness or of a brightness which, though not equal everywhere, shows no symmetrical distribution with respect to a vertical plane through the sun, or, finally, if the 46° circle is ever recorded as complete with its lowest point above the horizon, my criticism of the theory so long current would fall. I venture to suggest to meteorologists that these two points are quite worthy of attention.

COMPLEX SOLAR HALO OBSERVED AT ELLENDALE, N. DAK.

By C. S. LING.

[Weather Bureau, Ellendale, N. Dak., March 17, 1922.]

The circumzenithal halo is convex towards the sun and less than a semicircle in extent. The opposite Kern's arc has previously been reported as also less than a semicircle. However, this arc, if due to reflection of light parallel to that which gives the circumzenithal halo by vertical crystal faces, should be a complete circle as reported by Mr. Ling.—EDITOR.

An unusually brilliant display of solar halos was observed at Ellendale, N. Dak., on February 12, 1922. At 10:52 a. m., a bright halo of 22° formed, and simultaneously brilliant parhelia developed to the right and left of the sun. There was formed at 11:02 a. m. a complete, bright white, parhelic circle; at 11:30 a. m., a bright halo of 46°; at 11:54 a. m., simultaneously, dim Lowitz arcs to the right and left of the sun, a brilliant upper tangent arc, and a bright, complete circumzenithal arc. Rainbow colors (red, orange, green, blue) with red nearest the sun were observed with all the phenomena, except the parhelic circle, which was a bright white band about 2° width, and the Lowitz arcs, which were dim gray.

The Lowitz arcs were of short duration. At the time of measurement they were about 1° width and extended downward from the parhelia of 22° on the parhelic circle, a distance of about 8° vertical angular measurement. Their direction of extension was apparently about parallel with the curvature of the halo of 22°.

When the circumzenithal halo was measured at 11:58 a. m. it was separated from the halo of 46° by about 4° to 5°. It formed a circle of about 10° radius around the zenith, was 50° from the sun, was bright throughout (not noticeably brighter on the side next the sun), and the red, orange, yellow, and blue colors were sharply defined. At this time the angular altitude of the sun was 30°. The measurements of the radius of the circumzenithal halo and its distance from the sun were difficult to obtain and no doubt as a result are slightly inaccurate. On account of the base plate of the theodolite, the phenomena having high angular altitudes could not be sighted, and it was necessary to obtain readings by observing the theodolite's field as it was passed by the colored bands of the halo of 46° and the circumzenithal halo. With the exception of the ending of the Lowitz arcs at 12:08 p. m., no perceptible change of appearance of the miscellaneous halo phenomena was noted between 11:54 a. m. and 12:38 p. m. From 12:38 p. m. the circumzenithal halo or portions of it were visible until 3:05 p. m. At about 3 p. m. the low clouds which accompanied the phenomena began dissipating rapidly. Between 2:25 p. m. and 3:05 p. m. the circumzenithal halo formed a brilliant circle around the zenith. During this phase the circumzenithal halo was tangent to an arc of about 120° length of the halo of 46°. At the point of tangency, and near to it, these phenomena were exceptionally brilliant. Throughout the circumzenithal halo and the arc of the 46° halo the red, orange, yellow, green, and blue colors were well defined. A series of readings were made by theodolite at 3:02 p. m., by which the sun's altitude was 20° and the circumzenithal halo 46° from the sun. The arc of the halo of 46° ended at 12:38 p. m., began again at 2:25 p. m., and ended finally at 3:05 p. m. The parhelic circle became dim at 12:50 p. m. and ended at 2:10 p. m. The halo of 22° and the parhelia of 22° were brilliant throughout the period of observation and ended simultaneously at 5:04 p. m.

The halos were preceded by light snow, beginning 9:02 a. m. and ending 10:24 a. m. High barometric pressure existed over eastern Montana and low pressure over Wyoming. Thin, slightly bunched clouds of stratus appearance prevailed. As the bunched clouds passed near the sun the phenomena brightened. The base of these clouds was about 400 meters' altitude. Ice crystals are believed to have existed underneath the clouds to within about 275 meters of the ground.

These conclusions relative to altitude of the clouds are based on observations of a pilot balloon. When about 275 meters above the ground the pilot balloon was very dim, and immediately after the second minute of observation (414 meters' altitude) abruptly entered the base of the clouds. The clouds formed as result of a small temperature inversion about 300 meters above the ground. It is not thought they were the result of a diurnal temperature change. It is more likely they occurred along the boundary between high and low pressure conditions, and that when the high pressure gained control over the weather conditions they dissipated. As indicated by the kite meteorogram record, this inversion was only about 0.5° C., and probably continued throughout the period of low clouds. While the clouds existed the wind velocities were about 50 per cent greater than before or afterward. Had the temperature gradient been greater at this inversion the clouds would have been denser and less favorable for halo formation. As low clouds in winter conditions are usually thick-layered, the complex halo phenomena that accompany the thinner type of low clouds are infrequent. When complex halo phenomena exist it seems that definite knowledge of the height of the clouds would be interesting. With summer conditions, low clouds consist of vapor particles and are not productive of halo formations.

AN ANGLE-MEASURING DEVICE FOR HALO OBSERVERS.

By JAMES H. GORDON.

[Weather Bureau, Yuma, Ariz., March 29, 1922.]

Upon the suggestion of Mr. H. F. Alciatore, of the Weather Bureau office at San Diego, I am submitting the description of a device designed for measuring the angular diameter of halos. As the only tools used were pocketknife, saw, hammer, plane, and a pair of dividers, the instrument could be made by anyone. It really has many uses. In addition to halo observing, it may be used as a crude sextant, accurate within a degree, for observing northern lights. It has enabled me to make clear points in regard to astronomy that were not otherwise well understood. Two observers a known distance apart could determine cloud heights with it and thus compute their velocity.

Description of instrument.—Base *H* (see fig. 1) is metal 5½ by 5½ inches, weighing about a pound. Bolted to it is a wooden piece, as shown. Frame or cradle for scale board is inch material, uprights securely nailed on; length over all, 9½ inches; height of uprights to centers, 5¾ inches. Scale board is inch material; diameter, 9¾ inches; length, 7¾ inches. Centering tube is set into the board 3¾ inches and extends about three-fourths inch beyond the board to form an axle for turning. Size of tube, 12-gage brass shell; aperture to admit ray of light is the caphole of the shell. On wood at back end of tube paper is pasted and a black spot marked on which the ray of light must center. Enough of the tube is cut away at the back end

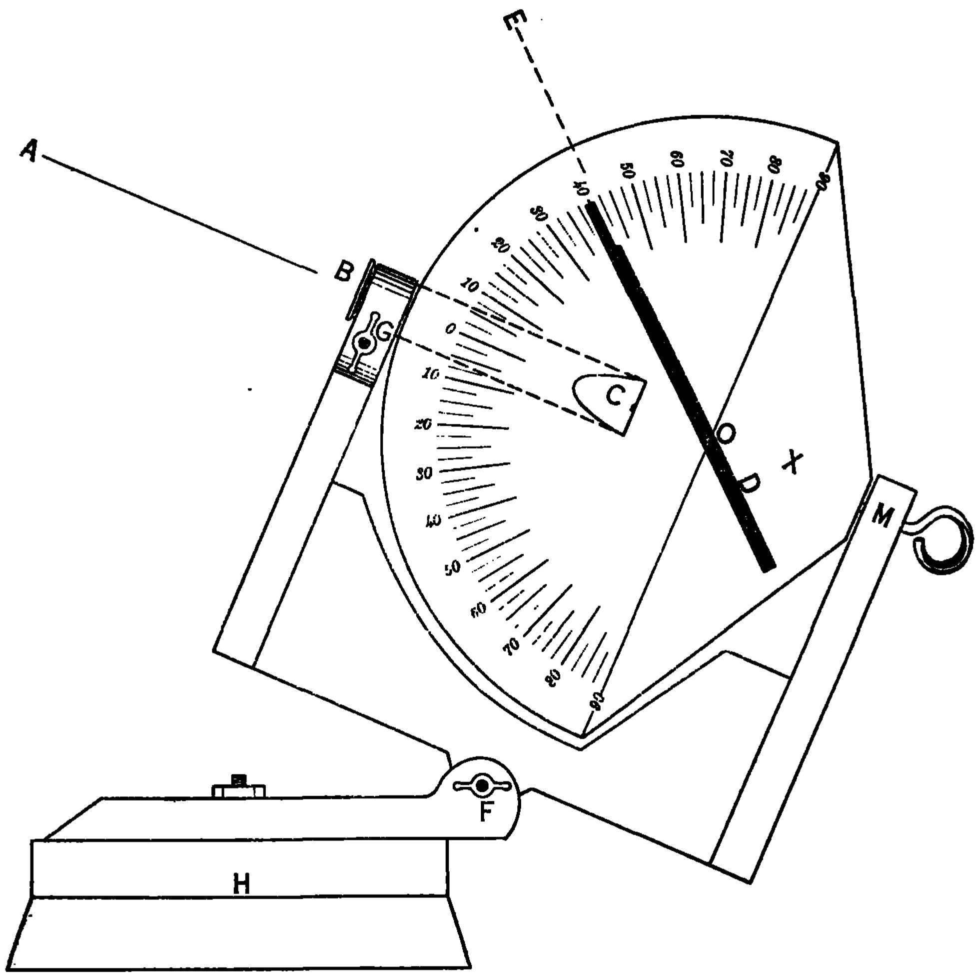

FIG. 1.—Device for measuring halos and other celestial phenomena.